Spectroradiometer Characterization for Colorimetry of LEDs

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A reference spectroradiometer for colorimetry of LEDs has been built at NIST and characterized for uncertainties in color measurement. The spectroradiometer, as shown in Fig.1, employs a double grating, scanning monochromator (concave grating, 1200/mm, F4.2, subtractive mode) covering a spectral range from 360 nm to 830 nm. The input optics are designed for irradiance geometry with a 7.5 cm integrating sphere having a 15 mm circular entrance aperture and 5 x 20 mm output opening, the image of which is focused onto the entrance slit of the monochromator, overfilling the slit. The spectroradiometer is calibrated against an integrating sphere source (15 cm, 2856 K), which is periodically calibrated against the NIST spectral irradiance scale [1].

The spectroradiometer was calibrated and characterized for the bandpass (BP) of 5 nm and 1 nm (FWHM). The settings for the entrance/exit slits and the center slit of the monochromator were adjusted, by iterative process, to obtain the best triangular shape of the slit scattering function (SSF) throughout the visible region for 5 nm BP and 1 nm BP, as shown in Fig.2. Then the wavelength scale has been calibrated in the range from 404.7 nm to 763.5 nm using 15 emission lines (11 for 1 nm BP) of lasers and discharge lamps. The results were fitted to a second order polynomial function for each bandpass (5 nm and 1 nm). The spectroradiometer was recalibrated against the reference sphere source with the wavelength correction, and the calibration factors at 5 nm BP and 1 nm BP were obtained.

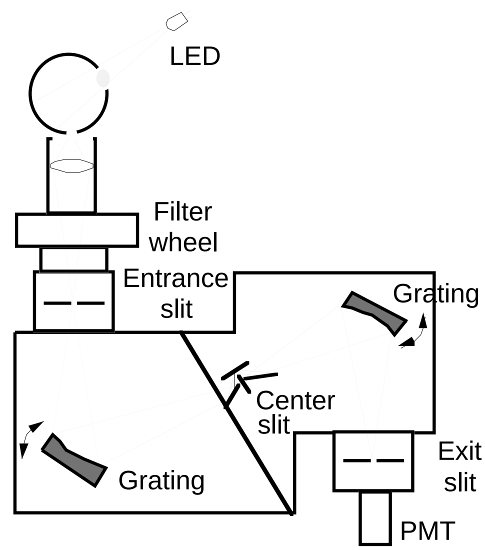

Figure 1. Arrangement of the NIST reference spectroradiometer for LED measurement.

The uncertainty of measurements for LEDs in chromaticity has been analyzed using the numerical methods [2] and modeling. The uncertainty components include wavelength errors, stray light of monochromator, the reference standard for spectral irradiance, linearity of the detector, and random noise of the signal. These uncertainty components affect the measured chromaticity coordinates in different ways than in the case of other general light sources because LEDs are quasi monochromatic sources, and thus, the requirements for spectroradiometers differ. There are also uncertainty components arising from the characteristics of LEDs including stability, temperature effect, spatial nonuniformity of color, and repeatability of alignment of LEDs.

To analyze the uncertainty arising from the wavelength errors, the sensitivity coefficients of (x, y) and (u', v') chromaticity coordinates of an LED model

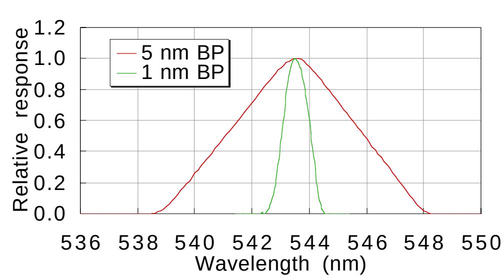

Figure 2. Slit scattering function of the NIST spectroradiometer at 543.35 nm.

with 20 nm spectral width were calculated using the numerical method. The results, as shown in Fig.3, indicate that the blue region (470 nm – 520 nm) is more sensitive than other regions. These data are used to evaluate uncertainty contribution for LEDs of different peak wavelengths.

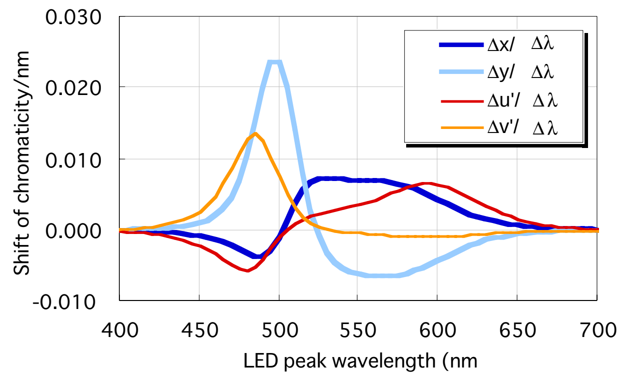

Figure 3. Sensitivity coefficients of *(x, y), (u',v')* for an LED model of 20 nm spectral width (FWHM) with varied peak wavelength.

The effect of the monochromator bandpass was evaluated using data from the simulation [3] and the measurement of several LEDs using the 5 nm and 1 nm bandpass with the NIST spectroradiometer. The results are shown in Fig.4. The deviations from the simulation results are considered to be contributions from other uncertainty components, particularly the wavelength scale correction.

The stray light of the monochromator also affect more critically for LEDs than for broadband sources. Fig.5 shows an example of the comparison of measurement of a red LED with a diode-array spectrometer and the NIST spectroradiometer, in which case the difference in (*x, y*) was (0.002, -0.0005). The final uncertainty budget for the NIST spectroradiometer is in progress.

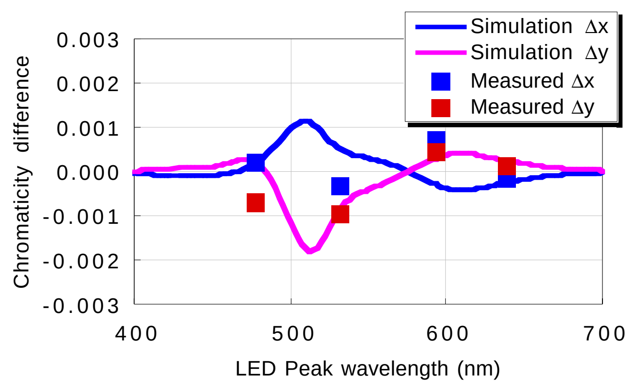

Figure 4. Effect of the monochromator 5 nm bandpass for LED measurement (difference in 5 nm bandpass and 1 nm bandpass)

This work was conducted when Kránicz stayed at NIST under the U.S.- Hungarian agreement on scientific cooperation.

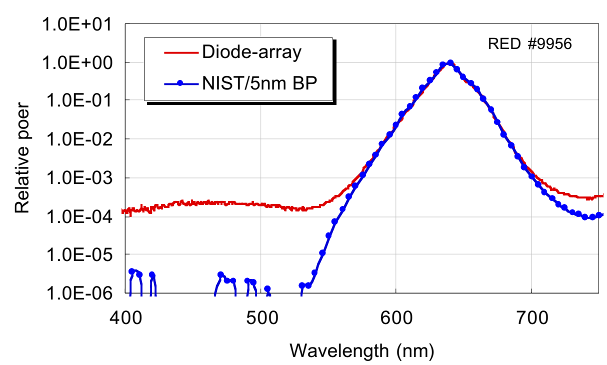

Figure 5. Spectral power distribution of a red LED in log scale, measured with a commercial diode-array spectroradiometer and the NIST

References

[1] Walker, J.H., Saunders, R.D., Jackson, J.K., and McSparron, D.A., Spectral Irradiance Calibrations, NBS Special Publication 250-20 (1987).

[2] Ohno, Y., Numerical Methods for Color Uncertainty, Proc., CIE Expert Symposium on Uncertainty Evaluation, January 2001 (to be published)

[3] C. F. Jones and Y. Ohno, "Colorimetric Accuracies and Concerns in Spectroradiometry of LEDs," Proc., CIE Symposium'99 - 75 Years of CIE Photometry, Budapest, 173-177 (1999)